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Indian Standard

CLASSIFICATION OF SMELTING REDUCTION (ALTERNATE IRON MAKING) PROCESSES

ICS 77.140.80

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

October 2000

Price Group 2

Sponge Iron and Smelting Reduction Sectional Committee, MTD 30

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Sponge Iron and Smelting Reduction Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Blast furnace is the predominant route for iron making as nearly 98 percent of the total iron production in the world comes through this route. The blast furnace process, however, needs hard coke and coals suitable for making hard coke are in short supply. The coking process is also capital intensive and has severe environmental effects. Hence efforts are on to develop a process for production of iron avoiding usage of coke.

Development of Smelting Reduction (S.R.) Processes for producing hot metal has gained significant thrust in recent years. Here the basic approach is to produce liquid iron in a reactor using iron oxide feed (ore or pellets) of zero or varying degree of pre-reduction and non-coking coals with oxygen and/or pre-heated air. The reactor gases are often used for pre-reduction of iron oxide feed. A large number of such processes have either been demonstrated or are being developed. More important processes in this group are COREX, ROMELT, HISMELT, AISI, DIOS, AUSMELT, etc.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

AMENDMENT NO. 1 JUNE 2008
TO
IS 14797 : 2000 CLASSIFICATION OF SMELTING REDUCTION (ALTERNATE IRON MAKING) PROCESSES

(*Foreword*, *para* 2, *line* 1) — Substitute '95' *for* '98'.

(*Foreword*, *para* 2, *lines* 5 *and* 6) — Insert 'FINEX' after 'COREX' and delete 'AISI, DIOS, AUSMELT' and insert 'PRIMUS' after 'HISMELT'.

[*Page* 1, *clause* 3, *tabular matter*, *Sl No.* (1), *col* 4] — Insert 'Finex' after 'AISI'.

[*Page* 1, *clause* 3, *Sl No.* (3), *tabular matter*, *col* 4] — Substitute 'Com' *for* 'com'.

[*Page* 2, *clause* 3, *Sl No.* (5)(b), *tabular matter*, *col* 4] — Insert 'Finex' after 'AISI'.

[*Page* 2, *clause* 3, *Sl No.* (6)(b), *tabular matter*, *col* 4] — Insert 'PRIMUS' after 'AISI'.

(*Page* 3, *Annex* A) — The Summary of Smelting Reduction Processes given on page 2 of this Amendment has been updated and is as follows:

Sl No.	*Process Name / Developer(s) / Country*	*Pre-reduction Reactor (Type)*	*Smelting Reactor (Type)*
1)	ELRED: Stora Kopperberg AB and Asea AB, Sweden	Fluidized bed at higher pressure using smelter gas	Smelting in DC arc furnace
2)	INRED: Boliden, Sweden	Partial reduction by flash smelting	Smelting and final reduction in EAF
3)	PLASMASMELT: SKF Steel, Sweden	Pre-reduction in fluidized bed in two stages using gas from plasma furnace	Smelting in plasma furnace
4)	COREX: Korf Stahl, Germany and Voest Alpine, Austria	Pre-reduction in a shaft furnace	Metling in smelter-gasifier using lump coal and injected oxygen
5)	HISMELT: Klockner, Germany, CRA, Australia and Midrex, USA	Pre-reduction up to FeO in circulating fluid bed using smelter off gas	Smelting in smelter-gasifier
6)	COMBISMELT: Lurgi, Germany and Mannesmann Demag, Germany	Pre-reduction in rotary kiln using coal.	Smelting and final reduction in EAF
7)	AISI Process: American Iron and Steel Institute and HYL, Mexico	Pre-reduction in shaft furnace using smelter off gas up to FeO stage	Molten iron bath reactor using coal and oxygen with post combustion and provision for direct steel making
8)	ROMELT (earlier FLPR— Ferrous Liquid Phase Reduction): Moscow State Institute of Steel and Alloys, Russia	Not required	Rectangular horizontal reactor with side lances and overflow type separator for slag and metal
9)	FINEX: Voest Alpine and Research Institute of Industrial Science and Technology, Korea Posco, Korea	Pre-reduction in series of fluidized bed reactors followed by compacting into briquettes; coal fines also as briquettes	Smelting in smelter-gasifier using oxygen and coal
10)	AUSMELT (AUSIRON): Ausmelt Limited, Australia	Oxygen and coal fines blown through top lance(s) into a liquid metal bath in a converter type furnace	Smelting in converter
11)	FASTMELT: Midrex, USA and Kobe Steel, Japan	Pre-reduction in Fastmet RHF	Melting in EAF
12)	ITMK3: Kobe Steel, Japan and Midrex, USA	Pre-reduction in Inmetco RHF	Melting in a SAF
13)	IDI (Redsmelt): Iron Dynamics, USA, Sumitomo, Japan and Mannesmann Demag, Germany	Pre-reduction of composite pellets of ore and coal in rotary hearth furnace	Smelting in EAF
14)	TECNORED: CAEMI, Brazil	Coal, ore, green pellets and briquettes reduced in a specially designed low shaft furnace	Melting in shaft furnace
15)	CLEANSMELT: CSM, Brazil and ILP, Italy	Reduction in Cyclone Converter Furnace	Melting in a melter-gasifier

(MTD 30)

Reprography Unit, BIS, New Delhi, India

Indian Standard

CLASSIFICATION OF SMELTING REDUCTION (ALTERNATE IRON MAKING) PROCESSES

1 SCOPE

This standard prescribes the method of classification of Smelting Reduction Processes based on the following criteria:

a) According to post combustion degree used,
b) According to whether they use oxygen gas or air in compressed or pre-heated form,
c) According to whether electricity is used in significant quantities as energy source,
d) According to fuel types,
e) Based on number of reactors used, and
f) Based on number of "Stages" or "Process zones" employed.

2 REFERENCE

The Indian Standard IS 1350 (Part 1) : 1984 'Methods of test for coal and coke (*second revision*)' is a necessary adjunct to this standard.

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Post Combustion Degree (PCD) is defined as :

PCD = (Percent CO_2 + Percent H_2O) / (Percent CO + Percent H_2 + Percent CO_2 + Percent H_2O)

where the percentages refer to the constituents in the gas exiting from the smelting reactor.

3.2 Volatile Matter (VM) — As defined in IS 1350 (Part 1).

3.3 Stage — A stage refers to a reaction zone or a processing zone where interconnected interaction or processing takes place. A stage has to be accommodated within a reactor and cannot be split between two reactors without changing the process.

3.4 Names of the processes have been used in abbreviated form in this standard. A brief explanation of these abbreviations has been given at Annex A.

4 CLASSIFICATION

For ease of analysis and evaluation of the Smelting Reduction (S.R.) Processes, attempts are being made to classify them into different groups. Depending upon the criteria used for classification, the groupings vary as shown below:

Sl No.	*Criterion*	*Class*	*Major Processes Under the Class*	*Remarks*
1)	According to level of PCD	a) Processes with high PCD more than 30 percent	Romelt, Hismelt, AISI	
		b) Processes with low PCD less than 30 percent	Corex	
2)	According to usage of oxygen or air	a) Processes using oxygen alone with little or no air	Corex, DIOS, AISI	
		b) Processes using air alone with little or no oxygen	Hismelt	
		c) Processes using air and oxygen in combination	Romelt	
3)	According to usage of electricity as energy source	a) Processes using electricity as energy source	Inred, Elred, Plasmasmelt, combismelt	
		b) Processes not using electricity as energy source	Corex, Romelt, Hismelt, DIOS, AISI	
4)	According to fuel types	a) Processes without restriction on VM of coal used	Romelt, Hismelt, DIOS, AISI	All metallurgical processes work better with low ash coals

Sl No.	*Criterion*	*Class*	*Major Processes Under the Class*	*Remarks*
		b) Processes with restriction on VM of coal	Corex	
5)	According to number of reactors used	a) Single reactor process	Romelt	Process developers of DIOS have kept their options open whether they would use two or three reactors
		b) Two reactors process	Corex, Hismelt, DIOS, AISI	
		c) Three reactors process	DIOS (?)	
6)	According to number of 'stages' 'Reaction zones' employed	a) One stage process (Fig. 1)	Romelt	Adopted from Corbett *et al* [1]
		b) Two stage process (Fig. 2)	Hismelt, DIOS, AISI	
		c) Three stage process (Fig. 3)	Corex, DIOS (?)	

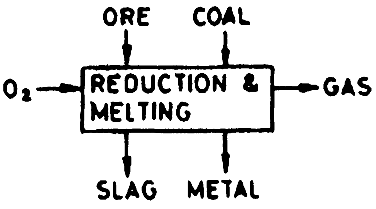

FIG. 1 SINGLE STAGE PROCESS

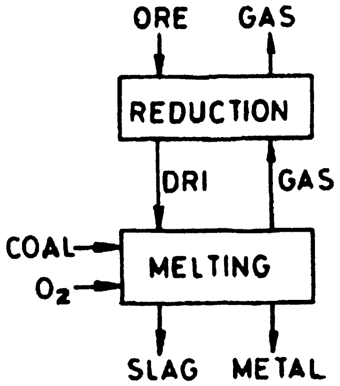

FIG. 2 TWO STAGE PROCESS

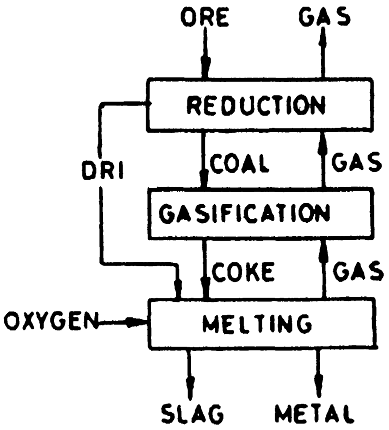

FIG. 3 THREE STAGE PROCESS

ANNEX A

(*Clause* 3.4)

SUMMARY OF SMELTING REDUCTION PROCESSES

Sl No.	*Process Name/Developer/ Country*	*Pre-reduction Reactor (Type)*	*Smelting Reactor (Type)*
1)	KRUPP-COIN, Krupp Stahl, Germany	Shaft/Fluidized bed using smelter off gas	BOF-type Converter using coal fines and oxygen
2)	B.S.C. British Steel Corporation UK	Shaft using smelter off gas	Reactor using coal and oxygen
3)	Hoogovens; Hoogovens Group, Netherlands	do	do
4)	Hoogovens/B.S.C Converted Blast Furnace Process; Hoogovens Group, Netherlands	do	do
5)	HISMELT; Klockner, Germany + CRA, Australia + Midrex, USA	Pre-reduction up to FeO in circulating fluid bed using smelter off gas	Horizontal cylindrical reactor use of pre-heated air in place of oxygen
6)	(EKSR, Excellent Kawasaki Smelting Reduction), Kawasaki Steel, Japan	Fluid bed using smelter off gas	Coke bed smelter (old Kawasaki Process) smelter gasifier using fluid bed of coal and oxygen (XR Process)
7)	KOBE; Kobe Steel, Japan + Midrex Corporation, USA	Midrex shaft using smelter off gas (with recycled and scrubbed top gas)	Converter using coal through bottom tuyere) and oxygen (through bottom and side tuyeres)
8)	SUMITOMO SC; Sumitomo Metal Industries, Japan	Shaft furnace using smelter off gas	Oxygen and pulverized coal injection in a coke bed smelter gasifier
9)	CIG; Japanese Iron and Steel Federation and National Swedish Board for Technical Development	Fluid bed with off gas from smelting furnace after post combustion	Reactor using coal and oxygen with post combustion
10)	NSC, Nippon Steel Corporation, Japan	Fluid bed with partially post combusted smelter off gas	Converter vessel using coal and oxygen (both from top and bottom)
11)	NNK; Nippon Kokkan, Japan	Pre-reduction in fluid bed	Melting in converter/ Bubbling bed for pre-reduction
12)	COREX; Korf Stahl, Germany and Voest Alpine, Austria	Pre-reduction of Ore/Sinter/Pellet in shaft	Melting in smelter gasifier using lump coal and injected oxygen
13)	DIOS; Japanese National Project on Direct Ore Smelting involving 5 major steelmakers and 3 other steelworks (Nissin, Nakayama and Godo)	Fluid bed pre-reduction using smelter off gas	Converter type vertical and tiltable vessel
14)	ELRED; Stora Kopperbergs AB and Asea AB, Sweden	Fluidized bed at high pressure using smelter gas	Smelting in a fixed type DC arc furnace
15)	INRED; Boliden, Sweden	Partial reduction by flash smelting	Smelting and final reduction in EAF
16)	PLASMASMELT; SKF Steel, Sweden	Pre-reduction in fluidized bed in two stages using gas from plasma furnace	Smelting in plasma furnace
17)	COMBISMELT; Lurgi and Mannesman Demag, Germany	Pre-reduction in rotary kiln using coal	Smelting and final reduction in SAF
18)	AISI Process; American Iron and Steel Institute, in collaboration with HYL, Mexico	Pre-reduction in shaft furnace using smelter off gas up to FeO stage	Molten iron bath reactor using coal and oxygen with post combustion and provision for direct steel making
19)	FLPR: Ferrous Liquid Phase Reduction process, also Romelt Process, Russia MISA (MOSCOW State Institute of Steels and Alloys)	Not required	Rectangular horizontal reactor with side lances and overflow type separator for slag and metal

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